Amendment under 37 CFR 1.111
Serial No. 09/728,889
December 6, 2001

REMARKS

By this amendment, claims 1, 9, 11 and 14 have been amended. Currently, claims 1-14 are pending in the application.

The drawings were objected to under 37 CFR 1.83(a). The Examiner indicated that the stator, winding connected to the inverter, microprocessor connected to the inverter disclosed in claims 1, 10 and 14, the toroidally wound stator disclosed in claims 5, 7 and 13, the squirrel cage rotor disclosed in claims 6 and 7, the digital signal processor disclosed in claim 8, the steps of controlling the inverter disclosed in claim 9 and the position sensor connected to the induction machine disclosed in claims 10, 11 and 14 must be shown or the feature(s) canceled from the claim(s). Applicants submit that Fig. 8 already contains many of these claimed features. Applicant submits another copy of Fig. 8 with the various elements labeled with reference numerals to help the Examiner's understanding of these elements. Fig. 8 specifically shows a programmable microprocessor/digital signal processor DSP (dashed line) operatively connected to the inverter A. The inverter A is shown with nine phases at the output. The induction machine C is shown in this example with nine phases. A position sensor D is also

shown connected to the induction machine C. This position sensor D is shown to be an incremental encoder, however, in general, any position sensor known in the art can be used.

Regarding the toroidally wound stator and the squirrel cage rotor, the application incorporates US Patent No. 5,977,679 by reference as stated on page 7. This patent clearly discloses the toroidally wound stator and the squirrel cage in its figures and specification. It is therefore respectfully submitted that it is not necessary to add these features to the drawings since they are clearly shown in a patent that is incorporated by reference. If the Examiner insists on maintaining the drawing objection regarding this point, then applicants will incorporate the relevant drawings and accompanying specification from this patent.

Regarding the drawing objection related to claim 9 for the "steps of controlling the inverter", applicants have amended claim 9 to recite "means for controlling the inverter" which is shown in Fig. 8. Therefore, it is respectfully requested that this drawing objection should be withdrawn.

Claims 2-4, 9 and 12 were rejected under 35 USC 112, second paragraph, as being indefinite. The Examiner indicated that the statement disclosed in claim 2, "program operates to control the

induction machined as a generator" needs more clarification. The Examiner indicated that he was unsure whether the program would make the motor work like a generator or it would only "control" the motor as a generator. The Examiner also indicated that it was unclear how the motor performs like a generator.

In response to these questions, applicants respond as follows:

The claim phrase "program operates to control the induction machine as a generator" means that any electric machine, by design, is an energy conversion apparatus and hence capable of reciprocal action as either transforming electrical energy to mechanical energy and vice versa. An induction machine when used to transform electrical energy to mechanical energy is a motor. When used to convert mechanical energy at its shaft from a prime mover to electrical energy is acting as a generator. However, being an inherently unexcited electric machine, the induction machine operates as a generator only when provided with a secondary means of electrical excitation. It is one function of power electronic controls to provide this excitation source in addition to controlling and processing electrical power to and from the machine. So, if we envision the microprocessor or DSP controller as containing the program (strategy in executable code to achieve a desired function)

then yes, the program is going to make the electric machine perform as either a motor or generator.

Is the program going to only "control" the motor as a generator?

First, the induction machine, or any electric machine for that matter is not a motor. It is a machine capable of performing either motoring or generating functions.

Second, under digital control and using appropriately rated power electronics the program is capable of achieving either motoring mode (1st and 3rd quadrant operation when viewed in the context of a torque-speed plane) or generating mode (2nd and 4th quadrant).

How can the motor perform like a generator? The controller (e.g., the program) monitors the induction machine shaft speed, in this application connected to an engine, the stator winding currents and bus voltage. From these measurements, the controller determines when to switch from motoring to the generating mode of operation. In the generating mode, the control commands the power electronic switches to impose voltages on the stator windings relative to the rotor position such that one component of the voltage sustains a magnetic excitation level in the airgap and a second component that is proportional to generator output power. It is believed that this description should assist the Examiner in understanding the language used in claim 2.

The Examiner also stated that regarding claim 3, it was unclear what the difference between the motoring operation and the generating operation mode is and how the induction machine switches from one mode to the other. The Examiner also indicated that it was unclear what each mode was for.

Regarding, what is the difference between the motoring operation and the generating operation mode, as discussed above, the distinction between motoring and generating is simply the distinction between the flow of the power direction on the dc link between the induction machine and its power processor (inverter) and the power supply (in this case a vehicle battery) and on the machine shaft, where a torque is either obtained from (motor) or supplied to the shaft (generator). Inside the machine itself the distinction between generating and motoring lies within the orientation of machine phase current and voltage orientation. When phase current is within a power angle of terminal voltage the induction machine is in motoring mode and when the phase currents are essentially 180 degrees displaced from their motoring orientation the machine is in generating mode. Under field oriented control the induction machine may switch between motoring and generating mode (at the same excitation level) within a matter of some microseconds.

Regarding how the induction machine is switched from one mode to the other, as just mentioned, once in vector control (e.g., field oriented control) the machine currents are controlled such that excitation (i.e., magnetizing current) is controlled independently from torque (motoring or generating) producing current. It is just a matter of a sign change in the torque producing current, whether the induction machine is motoring (+ sign) or generating (- sign) as this determines the direction of power flow at the terminals.

Regarding the Examiner's question, what is each mode for, in an automotive application it requires motoring mode to execute engine cranking, launch assist and boosting. By launch assist, it means adding torque to the vehicle power train to assist the vehicle acceleration from standstill and hence improve its performance. By boosting it means the addition of electric torque to the engine produced torque to assist the vehicle in passing, lane change, and other maneuvers that are typically a short duration and within the energy capacity of the on-board battery supply. By generating mode it means the ability of the induction machine to generate power to sustain the battery state of charge and to maintain the electrical loads on the vehicle as well as to do opportunity charging (e.g., recuperation of vehicle kinetic energy and replenish the battery).

Regarding claim 9, the Examiner indicated that he was unclear what the steps for the controlling the inverter are. This claim has been amended to recite "means for controlling said inverter by vector control". The inverter is controlled in the conventional manner through the signals to the power switch gates that are complementary between top and bottom switches in each phase leg. This means that a switch turn ON is delayed from a switch turn OFF to allow time for current decay in the outgoing switch. In this way, the destructive event known as inverter shoot through wherein short circuit current would flow from the battery through top and bottom switches that are in series is prevented.

Therefore, it is submitted that claims 2-4, 9 and 12 are definite and thus it is respectfully requested that the rejection should be withdrawn. If the Examiner believes that any of these claims should be amended to clarify the above aspects, he is requested to suggest language to clarify these claims.

Claims 1-4 and 8-12 were rejected under 35 USC 102(b) as being anticipated by Le. The Examiner stated that Le discloses an induction machine with a stator 14 and rotor, the stator 14 having a plurality of phase windings A, B, C and an inverter 12 with a plurality of switches (Fig. 2) and the inverter being

connected to the digital signal processor 70. The Examiner also stated that Le invention also comprises a position sensor 16. This rejection is respectfully traversed in view of the amendments to independent claims 1 and 11 and the following remarks.

The present invention relates to a system comprising an induction machine with a stator and a rotor; an inverter and a programmable microprocessor. The microprocessor (or DSP) includes a means for operating the induction machine using pole phase modulation. The system also includes a position sensor connected to the induction machine for providing a position indication that is indicative of a relative position of the rotor and the stator. The stator for the induction machine has a plurality of phases. In the case of Le, the phase number is restricted to 3, as is typical of the state of the art. However, in the present application, high phase order systems, typically 9, that are amendable to pole-phase-modulation are needed. The purpose of pole-phase modulation is to simultaneously change the number of stator and rotor poles and thereby adjust the machine operating characteristics to the number of stator and rotor poles. This adjusts the machine operating characteristics to the application requirements.

N/C

N/C

In Le, he discusses digital control of a Brushless DC Motor (BDCM) that is typically a permanent magnet synchronous machine having distinct, fixed number of permanent magnet poles on the rotor. Even if Le or Le in combination with some other patent was used, this type of system could not be implemented because a conventional permanent magnet machine, such as BDCM, has a predefined, unchangeable number of poles on the rotor. In fact, to attempt to alter the pole number in a BDCM would alter its performance and render it useless because the stator windings would not be compatible with the number of rotor poles. Thus it is submitted that Le or any of the other prior art of record does not disclose a means for operating the induction machine using pole phase modulation.

Claims 5-7, 13 and 14 were rejected under 35 USC 103(a) as being obvious over Le in view of Sawyer et al. The Examiner stated that Le does not show a squirrel cage rotor and a toroidally wound stator. The Examiner stated that although Le does not disclose a squirrel cage and a toroidally wound stator, Sawyer et al. disclose for the purpose for providing a balanced energy field between the stator and the rotor and lowering the harmonics, a toroidally wound stator (column 14, lines 25-26) and a squirrel cage rotor (Fig. 1). The Examiner concluded that it

would have been obvious to make an induction machine comprising an inverter, windings, a wound stator and a squirrel cage rotor for the purpose for providing a balanced energy field between the stator and the rotor and lowering the harmonics as disclosed by Sawyer et al. This rejection is respectfully traversed.

Sawyer discloses in column 14 a manufacturing process to realize low harmonic content induction machines. Thus applicant submits that Sawyer used the word "toroidal" incorrectly when in fact he meant "annular". Sawyer describes is the manufacturing sequence of producing machine stator laminations by first starting with annular punchings that are then subjected to a carefully planned sequence of slot punchings to achieve harmonic minimization. Thus, applicants submit that Sawyer does not disclose either a toroidal winding or pole phase modulation. In fact, Sawyer also states that the machine stator core is wound in the conventional manner in column 14.

Thus, one of ordinary skill in the art would not have combined Sawyer into Le to produce the claimed invention. Specifically, neither reference discloses using pole phase modulation in the manner claimed.

Therefore, applicants respectfully submit that the application is now in condition for allowance and an action to this effect is respectfully requested.

If there are any questions or concerns regarding this application, the Examiner is requested to telephone the undersigned at the telephone number listed below.

Respectfully submitted,

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

Submitted herewith is a marked-up version of the specification and claims to show changes made in the foregoing Amendment.

IN THE CLAIMS

Claims 1, 9, 11 and 14 have been amended as follows:

-- 1. (Amended) A system comprising:

an induction machine with a stator and a rotor, said stator having a plurality of phase windings;

an inverter having a plurality of solid-state switches with appropriate controls and having the same number of phases as said induction machine, said inverter being connected to selectively energize said windings; and

a programmable microprocessor operatively connected to said inverter and including a program for controlling said inverter that includes means for operating said induction machine using pole phase modulation.--

--9. (Amended) A system according to claim 1, wherein said microprocessor further includes [steps] <u>means</u> for controlling said inverter by vector control.--

--11. (Amended) A system comprising:

an induction machine with a stator and a rotor, said stator having a plurality of phase windings;

a position sensor operatively connected to said induction machine for providing a position indication that is indicative of a relative position of said rotor and said stator;

an inverter having a plurality of solid-state switches with appropriate controls and having the same number of phases as said toroidal induction machine, said inverter being connected to selectively energize said windings; and

a programmable microprocessor operatively connected and including a program to implement vector control of said induction machine, said microprocessor [also] <u>includes means for</u> controlling said inverter so that said induction machine operates with pole phase modulation.--

--14. (Amended) An automotive propulsion system including a system comprising:

an induction machine with a toroidally wound stator and a squirrel cage rotor, said toroidally wound stator having a plurality of phase windings;

a position sensor operatively connected to said induction machine for providing a position indication that is indicative of a relative position of said rotor and said stator;

an inverter having a plurality of solid-state switches and a control system, said inverter having the same number of phases as said toroidal induction machine, said inverter being connected to selectively energize said windings; and

a programmable digital signal processor operatively connected to said induction machine, said programmable digital signal processor including a program to implement vector control of said induction machine, said programmable digital signal processor includes means for controlling said inverter so that said induction machine operates with a predetermined number of poles using pole phase modulation. --